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Cover image: A seagrass meadow (*Thalassia hemprichii*) at Inhaca Island, Mozambique (© José Paula, 2017)

Effect of Salinity on the Survival and Growth of Rufiji Tilapia (*Oreochromis urolepis urolepis*) Fry

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Abstract

Survival and growth of Rufiji tilapia (*Oreochromis urolepis urolepis*) fry were determined under controlled salinity conditions of 5, 15, 25 and 35 ppt for 56 days. Experiments were carried out in 12 concrete tanks of 1 m^3 volume each with three replicates for each treatment. Data was recorded at fourteen days intervals where weight measurements (g) of fry were recorded to the nearest 0.01 g. One Way Analysis of Variance (ANOVA) was used for data analysis. Results showed significant differences in the final body weight, specific growth rate, weight gain and daily growth rate at different salinity levels. The fry reared at a salinity of 25 ppt had the highest final body weight, specific growth rate, weight gain and daily growth rate, while the lowest was recorded at the salinity of 5 ppt. There was no significant difference in survival rate among the fry reared at different salinity levels. Dissolved oxygen (DO) was significantly different at different levels of salinity but temperature and pH showed no significant differences. The results suggest that under proper management, Rufiji tilapia can be farmed in brackish and sea water by coastal communities along the coast.

Keywords: *Oreochromis urolepis*, growth, survival rate, salinity tolerance.

Introduction

Oreochromis is a genus of fish in the *Cichlidae* family native to Africa and the Middle East (Balarin and Hatton, 1979; Trewavas, 1983). It has however been introduced to other areas of the world during the 20th century (Balarin and Hatton, 1979; Trewavas, 1983; Klett and Meyer, 2002). *Oreochromis* is one of the most widely cultured fish in the world in terms of production quantity and is the second most farmed fish after the Carps (Jaspe and Caipang, 2011; Madalla, 2008). Most important and abundant in production, capture and aquaculture, is Nile tilapia (*Oreochromis niloticus*), followed by the Blue tilapia (*Oreochromis aureus*); and Sabaki tilapia (*Oreochromis spilurus*) (FAO, 2010; Fridman *et al*. 2011). Tilapias have many good farming qualities which allow them to be reared in most types of aquaculture production systems, from very simple traditional systems to highly intensive systems (Hussain, 2004; Jaspe and Caipang, 2011). Rapid growth, resistance to poor water quality and high fecundity are among their many good farming qualities (Jamil *et al*. 2004).

Although tilapias are considered freshwater species, some of them have tolerances to salinity and are believed to have evolved from marine ancestors (El-Sayed, 2006; Awal *et al*. 2012). However, the ability to tolerate salinity depends on species, strain, size, adaptation time and other environmental factors. For example, Mozambique tilapia (*Oreochromis mossambicus)* is the most salinity-tolerant species. It is capable of tolerating salinities as high as 120 ppt, and breed and reproduce well at 49 ppt (El-Sayed, 2006). In contrast, Nile tilapia is the least salinity-tolerant species (Cnaani and Hulata, 2010). Juveniles and fry of Nile tilapia prefer low salinities of less than 10 ppt and may die if salinity rises above 14 ppt (Nandlal and Pickering, 2004). Most of tilapias used in high salinity systems are hybrid strains, particularly the hybrids of *O. mossambicus* x *O. urolepis hornorum, O. mossambicus* x *O. niloticus* and *O. spilurus* x *O. niloticus* x *O. aureus* (Watanabe *et al*. 2002; Jaspe and Caipang, 2011; El-Zaeem *et al*. 2012; Roshada *et al*., 2002). Popular hybrids are the Florida red tilapia, a hybrid of *O. aureus* x *O. Mossambicus*, *O. mossambicus* x *O. urolepis hornorum, O. aureus* x *O. niloticus* tilapias (Watanabe *et al*., 1998; El-Zaeem *et al*. 2012) and Taiwanese red tilapia, *O. mossambicus* x *O. niloticus*. The suitability of these hybrids for culture in brackish and sea water is attributed to the salinity tolerance exhibited by their parental species which are known to be moderate (eg. *O. niloticus* and *O. aureus*) to high (eg. *O. mossambicus* and *O. urolepis hornorum*) (Watanabe *et al*. 1998).

This is the first study on the effect of salinity on the survival and growth of Rufiji tilapia (*Oreochromis urolepis urolepis*). Rufiji tilapia is distributed in the south eastern rivers, reservoirs and satellite lakes in Tanzania, where it is an economically important fish to the communities of these areas (Lamtane *et al*. 2008). Having shown high salinity tolerance, Rufiji tilapia offers considerable potential for culture in saline waters to expand the farming area, and improve income and livelihoods of coastal communities. However, unlike other tilapias, studies on the potential of Rufiji tilapia for aquaculture are limited. Taxonomy, systematics and distribution of Tilapiine fishes of the genera *Saratherodon*, *Oreochromis* and *Danakilia* are documented by Trewavas (1983). Studies on these genera include mitochondrial DNA sequencing (Nagl *et al*. 2001), and the role of salinity on growth performance of *Oreochromis niloticus* and *Oreochromis urolepis* hybrids (Mapenzi and Mmochi, 2016). Generally, studies on tilapia farming have focused on other tilapia species such as Nile tilapia (Farag, 2003; Akel and Moharram, 2007; Tahoun *et al*., 2008; Sumi *et al*. 2011), *O. shiranus chilwae*, *O. karongae*, *O. shiranus*, and *Tilapia rendalli* (Likongwe *et al*. 2002), *Tilapia guineensis* (Chukwu and Okpe, 2006), *Sarotherodon melanotheron* (Gabriel *et al*. 2007; Akinrotimi *et al*. 2010; 2013; Cnaani and Hulata, 2010), and tilapia hybrids such as *O. niloticus* x *O. urolepis hornorum* (Watanabe *et al*. 1998), and the Taiwanese red tilapia, *O. mossambicus* x *O. niloticus* (Yi *et al*., 2002; Pang, 2005). With increasing demand placed on freshwater resources for public water supplies, agriculture, and aquaculture, especially in arid regions, combined with declining capture fisheries, development of a tilapia species that can tolerate high salinity would increase fish availability and contribute to the current demand for fish in Tanzania of around 400,000 MT (Principal Secretary, Ministry of Agriculture, Livestock and Fisheries (http://www.tanzaniatoday.co.tz/news/tanzania). Rufiji tilapia appeared to be a good candidate for this. Therefore, this study investigated the survival and growth of Rufiji tilapia fry under controlled salinity conditions with the aim of producing tilapia fingerlings that can tolerate high salinity for culture in marine waters.

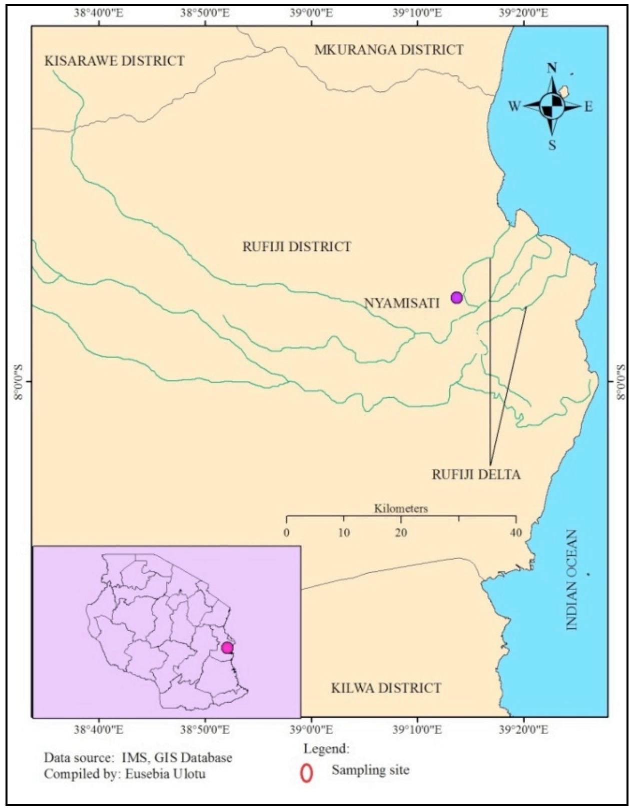

Figure 1. Map of the Coast Region of Tanzania showing the broodstock collection site.

Materials and Methods

The experimental system set up for this study was located at the Institute of Marine Sciences Mariculture Centre (IMS-MC) located at Bweni Village, Pangani District in Tanga Region, Tanzania (05° 26´ 0˝ S and 38° 58´ 0˝ E). Fry used in this study were produced by Rufiji tilapia broodstock which were collected from Rufiji District at Nyamisati Village in the Rufiji Delta (Fig. 1).

Experiments were carried out in 12 concrete tanks with dimensions of 1m x 1m x 1m (1m^3 volume) for 56 days to test the effect of salinity on the survival and growth of Rufiji tilapia fry. Rufiji tilapia broodstock were acclimatized at different salinity levels of 5, 15, 25 and 35 ppt in triplicates during spawning for the production of fry prior to the experiments. Three fish with a male to female ratio of 1:2 were stocked in each tank. Acclimatization to each salinity level was carried out through daily increments starting from 2 ppt, by mixing freshwater from a borehole at the centre (salinity 2 ppt) with seawater (salinity 36.92 ± 0.45 (MEAN ±SE ppt). Fry which were produced in each salinity level were collected and transferred to similar sized tanks (1 m^3) with similar salinity to the one in which they were produced (5, 15, 25 and 35 ppt). Experimental tanks were randomly arranged for each salinity level making a total of 12 tanks interspersed amongst the replicates of other salinities to avoid systematic differences. After production, fry from each replicate of each salinity level were collected, counted and weighed while in water to avoid handling stress. Weight measurement was done to the nearest 0.01 g using a sensitive digital scale (Sinbo; Model No: SKS 4511). Measurements were taken prior to the experiments to determine the initial weight. Further measurements were taken during data collection. The mean weight was estimated by dividing the total weight by the number of fry. Due to low numbers of available fry, they were later batched into three replicates of 40, 40, 38 and 8 fry per salinity level of 5, 15, 25 and 35 respectively. Salinity levels were maintained by taking records daily using a refractometer. Where it was necessary freshwater or saline water was added to the tanks.

Water temperature (°C), dissolved oxygen (mg/L), pH and salinity were monitored twice daily between 06:00 and 07:00 am and between 04:00 and 5:00 pm. Water temperature and dissolved oxygen concentrations were monitored using an oxygen meter (YSI DO 200), while pH was measured with a pH meter (CE HI 98128) and salinity was measured using a hand held refractometer (Extech instruments RF20).

Fry were fed a powdered mash diet containing 30% crude protein made from maize bran (11.08% CP) and fish meal (64.43% CP). The diet was formulated using the Pearson Squire formula. Feed was given at a rate of 20% of body weight for the first four weeks and adjusted to 15% of body weight per day to the end of experiment. Feeding rate was adjusted every two weeks according to changes in the weight of the fry. Data were collected at 14 day intervals. Individual weight of fry was estimated in each replicate by dividing the weight of all sampled fry by the number of fry in each sample (all fry in the experimental tanks were taken as a sample). The individual weight of fry in each salinity level was then calculated by dividing the obtained means from each replicate by three.

Generated data were subjected to the following formulae to calculate different growth indices and survival rates:

1. Weight gain WG (g) $= W_f - W_i$ where WG = weight gain, Wi = initial weight of tilapia fry and Wf = final weight of fingerling.
2. Specific growth rate (SGR): SGR%= [(ln W_2-ln W_1)/(t_2-t_1)] x100 (% day^{-1}), where W_1 and W_2 are the initial and final weights of the fish at times t_1 and t_2 (days) respectively.
3. Daily Growth Rate (DGR): $DGR = \frac{Wf - Wi}{t}$, where DGR = daily growth rate, Wf = final weight Wi = initial weight and t = time spent (days).
4. Percentage survival rate (SR): SR, % = $\frac{Nf}{Ni}$ x 100, where Nf = final number of fish and Ni = the initial number of fish.

Statistical analysis was carried out using InStat statistical software package. Data were tested for homogeneity of variance to guard against violation of the assumptions of parametric statistics. One way Analysis of Variance (ANOVA) was used to determine differences between treatment means, but before analysis, percentage data were subjected to arcsine transformation. Tukey-Kramer means multiple comparison tests were done where significant differences existed among treatments. All analyses were considered significant at a p value less than 0.05 (Zar, 1996). Results are presented as mean ± standard error of the mean (SE).

Results

The results of environmental parameters recorded in fry rearing tanks are shown in Table 1. Results showed no significant differences in any of environmental parameters recorded (ANOVA, p> 0.1).

Table 1. Water quality parameters in fry rearing tanks.

Salinity (ppt)	pH	Temperature (°C)	DO (mg/L)
5	8.53±0.03	28.43±0.20	3.05±0.09
15	8.58±0.05	28.13±0.15	3.04±0.13
25	8.47±0.03	28.56±0.20	3.32±0.09
35	8.57±0.05	28.23±0.13	3.28±0.09

Results indicate that weight increased with time (Fig. 1). Growth and survival rate of Rufiji tilapia fry reared at different salinities is are shown in Table 2. Fry at 25 ppt had the highest final body weight, specific growth rate, percentage weight gain and daily growth rate. They were followed by those reared at a salinity of 35 ppt. Significant differences were recorded in each growth parameter i.e. final body weight ($p < 0.037$, DF =59, F = 3.05), specific growth rate ($p < 0.03$, DF = 59, F = 3.33), percentage daily weight gain ($p < 0.05$, DF =59, F = 4.77), and daily growth rate ($p < 0.003$, DF = 59, F = 5.25). However, percentage survival rate did not differ significantly at different salinity levels ($p > 0.23$, DF = 59, DF = 1.46).

Discussion

The growth of Rufiji tilapia fry used in this study differed significantly at different salinity levels indicating that salinity had an influence on their wellbeing. The highest growth (final weight, specific growth rate, weight gain and daily growth rate) observed at a salinity of 25 is evidence that Rufiji tilapia prefers a brackish environment. However, these results may have occurred due to the production method used in producing the fry. The broodstock which produced the fry were acclimatized gradually to different salinity levels during spawning. It is probable that the offspring of the broodstock kept in high salinities during fry production (spawning, incubation until hatching of eggs) were better able to tolerate high salinity than those spawned at lower salinity levels. These results suggest that fry produced at higher salinities have a better chance of growing successfully in saline environments as compared to those produced at lower salinities. Similar observations have been reported elsewhere for different tilapia species by Likongwe *et al.* (1996), Watanabe *et al*. (1998), Romana-Eguia and Eguia (1999), Yi *et al*. (2002), Ridha (2008) and Iqbal *et al*. (2012). For example Likongwe *et al*. (1996) reported that early exposure through spawning and incubation to elevated salinities can effectively enhance salinity tolerance in tilapia fry resulting into higher growth performance at high salinities. Iqbal *et al*. (2012) observed higher weight gain in *O. niloticus* reared in sea water (40 ppt) as compared to those reared at lower salinity of 8 ppt. Yi *et al*. (2002) reported higher growth performance in Thai red tilapia in brackish water with salinity of 10 ppt than in fresh water. However, growth of Thai red tilapia was decreased with increase in salinity above 10 (20 and 30 ppt). Yi *et al*. (2002) suggested that although Thai red tilapia are euryhaline, their growth is limited in saline environments. In that study fish grew faster during the first two months followed by a decline in growth rate towards the end of the experiment. Likewise, Ridha (2008) reported that salinity tolerance limits are related to the growth stages at which the fish are, and smaller fish are more tolerant than bigger ones. Iqbal *et al*. (2012) reported that salinity tolerance in tilapias depends on species, strain, size, adaptation time, and prevailing environmental factors.

The better growth performance observed in Rufiji tilapia fry reared at the higher salinity of 25 ppt in this study can also be related to the reduced mobility of fish which was noticed in tanks with higher salinities (25 and 35 ppt). The energy saved from this reduced mobility could possibly result in enhanced growth. Similar observations on different tilapia species was reported by Awal *et al*. (2012) on the effect of salinity on oxygen consumption in tilapia. Findings in their

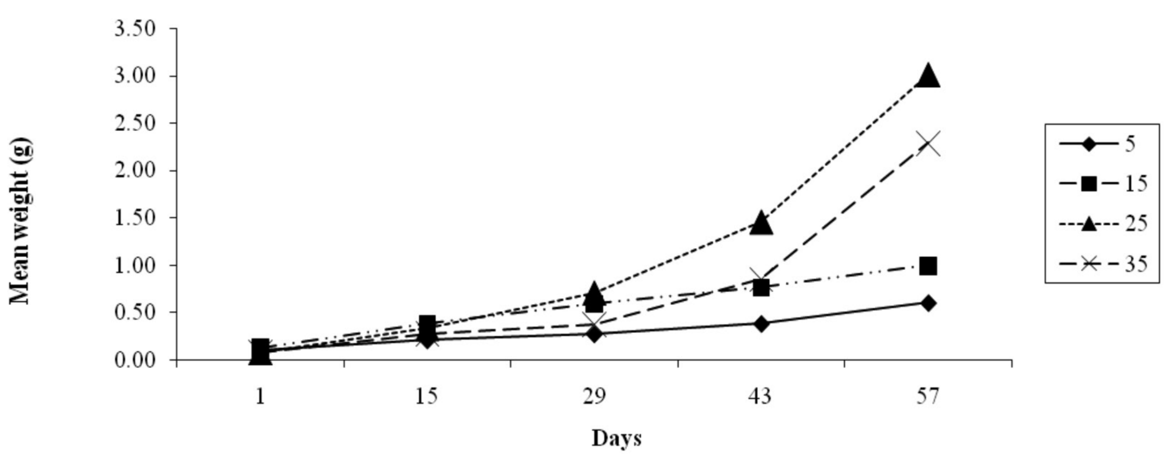

Figure 2. Weight increment of Rufiji Tilapia fry at different salinities over time.

Table 2. Growth performance of Rufiji Tilapia fry at different salinities.

Salinity	Initial wt(g)	Final wt (g)	SGR (%)	WG	DGR (g/day)	SR (%)
5	0.09	0.32±0.04[a]	2.47±0.46[a]	0.11±0.03[a]	0.007±0.00[a]	95.67±1.75[a]
15	0.08	0.56±0.01[a]	3.07±0.50[a]	0.27±0.04[a]	0.008±0.00[a]	97.37±0.66[a]
25	0.08	1.07±0.24[b]	4.86±0.70[b]	0.49±0.15[b]	0.034±0.01[bc]	92.86±1.77[a]
35	0.08	0.56±0.21[a]	3.07±0.57[a]	0.44±0.14[a]	0.031±0.01[ac]	97.50±2.02[a]

[a,b,c] Mean in the same columns with different superscripts are significant different at ($P<0.05$) Tukey –Kramer multiple comparison test

study indicated that tilapia reared at high salinities demonstrated reduced movement and high growth performance, suggesting that reduced activity at high salinities resulted into reduced metabolic cost. Some scientists have also related the higher growth performance of tilapia at high salinities to increased feed intake when reared at higher salinities (Ridha, 2008; Cnaani and Hulata, 2010; Iqbal *et al*. 2012). Watanabe *et al*. (1998) related similar findings in Florida red tilapia to increased food consumption and lowered food conversion ratio. Gabriel *et al*. (2007) related the high growth at high salinity with stress saying that during acclimation at high salinity fish behaved similarly to those cultured at high stocking densities in intensive culture systems, where feed intake is increased. Lower energy expended for osmoregulation in iso-osmotic saline waters has also been related to higher growth performance in some tilapia species reared at high salinities. Ridha (2008) reported that tilapia species which were grown in 50% seawater had better or similar growth than similar tilapia species which were reared in freshwater; suggesting that lower energy was expended for osmoregulation in iso-osmotic saline waters (12 ppt) than in freshwater. This suggests that increased food intake in tilapias reared in high salinities results in faster growth than those reared in fresh water. The present study confirms that Rufiji tilapia fry grow better if they are produced and reared in brackish water up to 25 ppt.

Rufiji tilapia fry reared at different salinities in this study tolerated salinity challenges at all levels and salinity had no effect on their survival rate. The ability to withstand different salinities was probably as a result of the method of breeding in which broodstock were acclimatized to different salinities during spawning. It is suggested that having been produced and reared in saline water of the same salinity has added to the ability of fry to overcome the effect of salinity. Similar observations were reported by Jonassen *et al*. (1997), Gabriel *et al*. (2011) and Yi *et al*. (2002). However, salinity tolerance in tilapia differs ontogenetically (Watanabe *et al*., 1998). Survival and growth in brackish or seawater may be affected by species, life stage at which exposure to high salinity occurs, the method of acclimatization to higher salinities. Schofield *et al*. (2011) suggested that although salinity is known to have no effect on the survival of tilapia, methods applied when introducing fish to high salinity is important. Gradual transfer has been reported to have a significant effect on tilapia growth and survival (El-Sayed, 2006). For example, high mortalities were reported by Watanabe *et al*. (1984) after a direct transfer of one day post-spawned Nile tilapia eggs from freshwater to different salinities with increasing mortalities with an increase in salinity. Contrary to their former study, Watanabe *et al*., (1998) observed high survival rate (between 84.3 and 96.8%) in fingerlings (8 and 12 g) of similar species which were directly transferred to salinity of 17 ppt, whereas significant mortalities occurred at salinities above 17 ppt. When the same size of fish was gradually acclimatized for two days, their survival rate ranged between 78 and 81% at salinities up to 30 ppt. Therefore, the findings of this study agree with other reported findings that salinity has no influence on the survival rate of tilapia as long as important conditions such as species, acclimatization method and life stage are taken care of.

The water quality parameters obtained in this study were not influenced by different salinities used. None of the parameters measured differed significantly between different levels of salinities to which the Rufiji tilapia fry were subjected. All parameters except dissolved oxygen were within the optimum ranges required for the growth and survival of tilapia. The main water quality parameters required for optimal survival and growth of tilapias are temperatures between 25 and 32 °C, dissolved oxygen between 3.0 and 5.0 mg/L and pH between 6.5 and 8.5 ppt (Rakocy, 2005). Although dissolved oxygen was slightly low in this study, the levels recorded are not a threat to the growth and survival of tilapia as they can grow and survive in waters with dissolved oxygen concentration down to 2 mg/L (Rakocy, 2005). Nevertheless, farmers are advised to maintain water quality parameters, including dissolved oxygen, within the recommended levels for attaining optimum survival and growth of Rufiji tilapia.

This study has revealed that Rufiji tilapia is capable of growing and surviving well in brackish waters. Under proper management the species offers potential for mariculture development in estuarine areas along the coast of Tanzania where there is an estimated 3000 ha of swamplands, estuaries and lagoons. These 'marginal' areas could be utilized for mariculture development to assist in addressing increasing fish demand, and alleviate competition for fresh water, especially in arid regions.

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